Renewable and Sustainable Energy Reviews 15 (2011) 5068–5080

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Review of current position and perspectives of renewable energy in the Republic of Macedonia with focus on electricity production

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ARTICLE INFO

Article history:
Received 14 December 2010
Received in revised form 17 June 2011
Accepted 8 July 2011
Available online 14 September 2011

Keywords:
Renewable energy sources
Position
Perspectives
Republic of Macedonia

ABSTRACT

Republic of Macedonia, as a candidate country for EU membership since 2005 will have to fulfill the targets set in the Directive 2009/28/EC on the promotion of electricity from renewable energy sources in the internal electricity market, in order to become member of the EU. The Directive defines renewable energy sources as energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.

In this paper, the current position and perspectives for utilization of renewable energy sources (RES) in the Republic of Macedonia as well as main problems and tools for promoting their development and utilization will be presented.

Contents

1. Introduction

Renewable energy sources became very important and attractive in the last decade. Power generation from renewable sources is growing from year to year and will continue to grow during the coming years. Republic of Macedonia is trying to attend this process and make big efforts to increase production of electricity from renewable energy sources.

At the end of September 2008 the International Energy Agency (IEA) has called for a major boost in renewable energy use, estimating that until the middle of the century nearly 50% of global electricity supplies will have to come from renewable energy sources [1].

Republic of Macedonia is a landlocked, mountainous country, with area of 25,713 km^3 and population of 2.1 million. Total consumption of energy in the country is around 126,000 TJ annually

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doi:10.1016/j.rser.2011.07.049

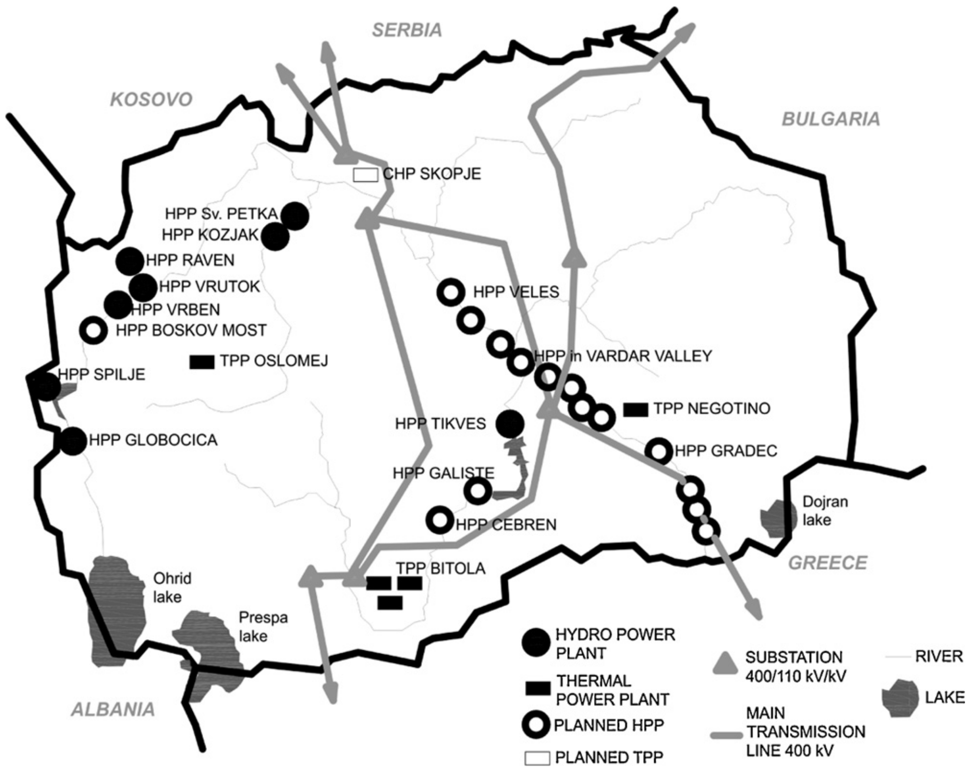

Fig. 1. Existing and planned capacities for electricity production along with existing main electro-energetic transmission lines in the Republic of Macedonia.

[2]. In primary energy consumption, oil accounts for 36%, coal for about 50%, natural gas 3–4%, and the remaining around 10% are hydro energy, wood and geothermal energy. Domestic energy production covers about 54% of the demand and 46% is provided from import.

While the countries of EU are largely investing to increase the share of renewable energy sources, becoming world leaders in "green electricity" production, Republic of Macedonia and the countries of the South East Europe (SEE) are facing immense problems in the area of electricity supply, frequent electricity shortages and continuous dependence on electricity import. The transition period and the process of reconstruction of energy sectors in these countries did not always go hand in hand with the development of alternative energy sources and the concept of sustainable development. Thus, the energy sector of the countries of SEE nowadays is distinguished with high energy intensity, low energy efficiency and lack of domestic renewable energy sources in the energy supply.

In a period when EU member countries are steadily approaching the binding target of 20% of the EUs overall energy consumption coming from renewables by 2020, Republic of Macedonia is only on the doorstep of introducing the RES in the energy market of the country.

2. Overview of electric power system in the Republic of Macedonia

Total installed capacity for electricity production in the country is 1581.365 MW. Installed capacity from thermal power plants is 1005 MW and installed capacity from hydro power plants is 576.365 MW. There are 3 thermal power plants: TPP Bitola (3 × 225 MW), TPP Oslomej (1 × 120 MW) that are lignite fired and TPP Negotino (1 × 210 MW) operating on heavy-oil and used as a backup. Also there are 7 bigger hydro power plants: HPP Vrutok, 172 MW; HPP Tikves, 116 MW; HPP Spilje, 84 MW; HPP Kozjak, 80 MW; HPP Globocica, 42 MW; HPP Raven, 21.6 MW; HPP Vrben, 12.8 MW; and 23 small hydro power plants with total installed power of 47.965 MW. Disposition of existing and planned electricity production capacities, as well as main transmission routes are shown in Fig. 1.

Electric power needs of the country grow continually. Despite the fact that in the last 5 years domestic producing capacities work with maximum of their power they are not sufficient to cover country's demand for electricity. In the year 2008, domestic production share was 69.8% and import share was 30.2% of the gross national electricity consumption (9,043,832 MWh) [3], presented in Fig. 2.

Company AD MEPSO – Skopje (Macedonian electro transmission system operator) is the owner of electro-energetic transmission network and has the role of operator of transmission electro-energetic network, operator of electro-energetic system and operator of the market [4].

ELEM AD – Skopje (Elektrani na Makedonija) owns seven largest hydropower plants and two thermal power plants fueled by lignite. Besides that, ELEM is owner and operator of smaller distribution system that supplies industrial consumers with heat and electricity. ELEM and MEPSO are state owned companies.

EVN Macedonia, as part of EVN group (Energie Versorgung Niederösterreich) – Austria, is the owner and operates with the largest electro-energetic distribution system in the Republic of Macedonia. It also supplies with electricity all regulated consumers connected to distribution network. Currently, company also owns 4 small HPPs.

TPP Negotino runs on heavy oil and has a license for production of electricity.

3. Legal and institutional aspect for implementation of RES in the Republic of Macedonia

Legal and institutional aspects, basic elements for implementation of RES, are provided through Law on energy [5] that promotes usage of RES in the country.

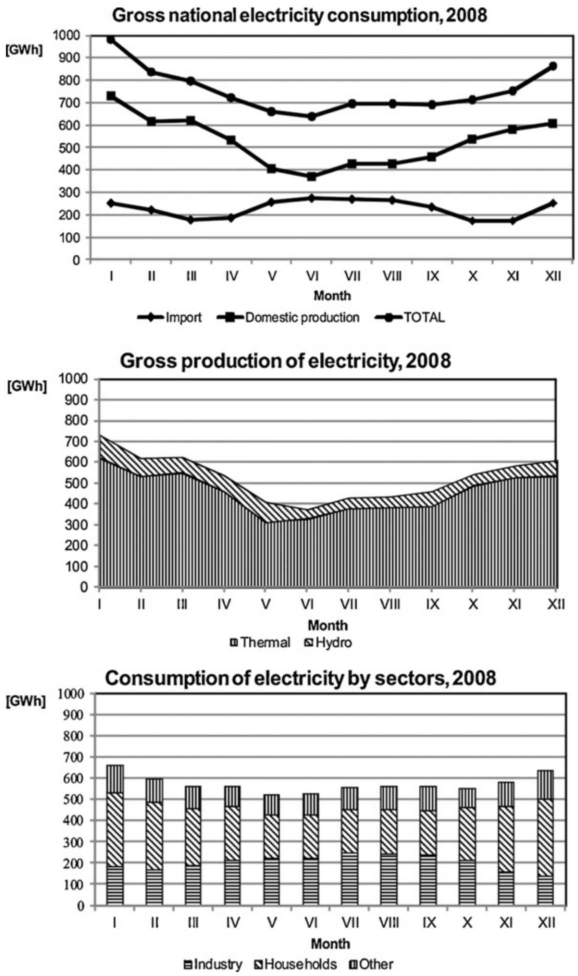

Fig. 2. Graphical presentation of electricity production and consumption in the Republic of Macedonia in the year 2008.

Energy Agency (EA) of the Republic of Macedonia (Agencija za energetika na RM) is responsible for issuing warranties of the origin of electricity generated by RES and from highly efficient cogeneration plants. EA also keeps register of the warranties.

Energy Regulatory Commission (ERC) of the Republic of Macedonia (Regulatorna komisija za energetika na RM) adopts Rulebooks and Decisions for feed tariffs for purchase of electricity from 'privileged' electricity producers as well as from highly efficient cogeneration plants.

Some of the important Rulebooks introduced so far:

- Book of regulations of the way and procedure for determination of feed-in tariff for purchase of electricity produced in small hydropower plants (SHPP) [6].
- Book of regulations of the way and procedure for determination and approval of utilization of feed-in tariff for electricity produced in wind farms [7].
- Book of regulations of the way and procedure for determination and approval of utilization of feed-in tariff for purchase of electricity produced in power plants using biogas derived from biomass [8] and its changes [9].
- Book of regulations of the way and procedure for determination and approval of utilization of feed-in tariff for purchase of electricity produced by photovoltaic systems [10] and its changes [9].
- Book of regulations of the way and procedure for determination and approval of utilization of feed-in tariff for purchase of electricity produced by power plants using biomass as a fuel [9].

In line with Books of regulations, ERC has introduced Price decisions regarding feed-in tariffs for purchase of electricity produced and offered on the market from small hydropower plants, wind farms, photovoltaic systems and power plants using biogas derived from biomass as fuel. Operator on the market is bound to purchase completely the electricity produced by the 'privileged' electricity producers. Privileged electricity producer must attach document to ERC, previously issued by EA, confirming that it uses RES for electricity production or electricity is produced in a highly efficient cogeneration process. These issues are already regulated by appropriate Books of regulations:

- Book of regulations of renewable energy sources used for electricity production [11].
- Book of regulations for issuing of warranties for the origin of electricity generated from renewable energy sources [12].
- Book of regulations for gaining a status of 'privileged' electricity producer generated from RES [12].

Energy Regulatory Commission established the following feed-in tariffs for electricity produced by:

- Newly constructed run-of-river small hydro power plants which have qualified as privileged producers with price from 4.5 to 12 €cents/kWh depending on the annual quantity of electricity delivered. The privileged producer is obliged to use the approved feed-in tariffs for a period of 20 years.
- Wind power plants, 8.9 €cents/kWh.
- Photovoltaic systems, original price 46 €cents/kWh for installed capacity up to 50 kW and 41 €cents/kWh for installed capacity greater than 50 kW. In meantime, these tariffs were changed and currently are: 30 €cents/kWh for installed capacity up to 50 kW and 26 €cents/kWh for installed capacity of 51–1000 kW.
- Power facilities that use biogas derived from biomass as fuel with original price of 13 €cents/kWh for installed capacity up to 500 kW, and 11 €cents/kWh for installed greater than 500 kW. These tariffs were later changed and currently are 15 €cents/kWh for installed capacity up to 500 kW and 13 €cents/kWh for installed between 501 kW and 2000 kW.
- Power plants producing electricity from biomass, 11 €cents/kWh for installed capacity up to 1000 kW and 9 €cents/kWh for installed between 1001 kW and 3000 kW.

In order to boost the usage of solar thermal collectors for water heating, the Government has subsidized first 500 households that installed solar thermal collector with up to 30% of the investment or up to amount of €500 per household. This action was organized few times, and in meantime the value added tax (VAT) for these systems was reduced from 18% down to 5%.

4. Technologies of RES and its perspective in the Republic of Macedonia

The share of the RES in the total energy supply and consumption in Macedonia is very low. Main renewable energy sources that can be exploited in the country are hydropower, wind, solar power, biomass and geothermal energy. Some of them, like the geothermal energy and the biomass, have been traditionally used in the energy consumption in Macedonia for heating purposes, yet with very low energy efficiency in their exploitation. For the rest of the renewable energy sources in Macedonia, for example the wind energy or the

Table 1
Hydropower potential of rivers in the Republic of Macedonia.

Rivers	Theor. (GWh)	Techn. (GWh)	Built (GWh)	Built./techn. (%)	Planned (GWh)	Planned/techn. (%)	Total (Built + planned) (GWh)	Total/techn. (%)
Vardar above Treska entry	1202	1084	488	45.02	140	12.92	628	57.93
Treska	377	347	190	54.76	60		250	72.05
Kadina river and Markova river	97	87						
Pčinja	265	201						
Topolka and Babuna	46	35						
Bregalnica	270	205	17	8.29			17	8.29
Crna	1098	944	184	19.49	604	63.98	788	83.47
Bosava	38	33						
Vardar – main course	1454	1336			1336	100.00	1336	100.00
Vardar total	4847	4272	879	20.58	2140	50.09	3019	70.67
Radika	438	338			134	39.64	134	39.64
Crn Drim	710	548	513	93.61			513	93.61
Crn Drim total	1148	886	513	57.90	134	15.12	647	73.02
Vardar and Crn Drim total	5995	5158	1392	26.99	2274	44.09	3666	71.07
Small HPP	671[a]	440[b]	76	17.27	197	44.77	273	62.05
Total	6666	5598	1468	26.22	2471	44.14	3939	70.36

[a] All 400 small HPP (total installed capacity of 255.5 MW and capacity factor (CF) = 0.3.
[b] Small HPP > 1 MW (total installed capacity of 168.5 MW and CF = 0.3), according to [14].

geothermal energy, there is still a lack of systematic mapping of the capacity of energy sources, and that is one of the reasons why they remain no or under explored.

Data for year 2008 indicate that share of RES in the total primary energy supply (TPES) of Macedonia was 15% [2]. If a comparison of this number with the EU average of 8–10% is made, the situation with the RES in Macedonia looks promising. However, an analysis of RES structure in the country shows that the share of RES in the energy supply in Republic of Macedonia and in EU countries is not on the same level. The major part of the renewable energy in Macedonia goes to firewood, which is largely used as a heating source, in a very inefficient and unsustainable way; while the second largest part goes to hydropower for electricity generation from large hydro power plants [13].

4.1. Hydropower

Hydropower plants as objects for generation of electricity conform to a group of 'clean technologies'. With the use of water as energy source for electricity production, hydropower plants are placed in the group of RES.

According to its geographical and relief configuration, Republic of Macedonia is landlocked country with mostly mountainous terrain. Best locations for hydropower plants are located in the western part of the country, on the right side of river Vardar. Thus, already built and planned hydropower plants are located in this part of the country.

The hydropower is regarded as renewable energy source when used for electricity production from small hydro power plants (SHPP) with installed capacity of up to 10 MW. In a study from 1982 [14], 406 locations for small and mini HPP with total installed capacity of 258 MW were determined.

Hydropower potential of river basins in the country, classified according to official documentation and performed studies are given in Table 1 [15].

According to the installed capacity, hydropower plants are divided into large and small HPP. Border between both types is not strictly determined, but for our occasions, big HPP are considered the ones with installed capacity greater than 10 MW, while the rest are placed in a group of small HPP.

Most of the existing large HPP in Republic of Macedonia are owned and operated by state owned AD ELEM, while only two are owned by EVN Macedonia. Most of the SHPP are property of EVN Macedonia, but there are few that are owned by municipal water supply utilities.

4.1.1. Existing large hydropower plants

Apart from HPP Kozjak and HPP Sv. Petka, most of the large HPPs are built in the 1960s and 1970s and after being in operation for more than 40 years they are revitalized. With the revitalization project, the biggest part of mechanical and electromechanical equipment has been replaced resulting with increased lifespan and improved performance of the turbines by increasing their installed capacity at the same time (Table 2).

Hydropower plants Vrben, Vrutok and Raven compose Mavrovo hydropower system with significant regulation ability. HPP Globočica and Špilje, together with Ohrid lake form cascade energy system on river Crn Drim. Third significant hydropower complex is on river Treska with HPP Kozjak, HPP Sv. Petka and HPP Matka. HPP Sv. Petka is in construction phase and should become operational in 2011 while HPP Matka has been revitalized in 2009. Total installed capacity of large hydropower plants is approximately 560 MW, with average annual production of electricity of around 1400 GWh.

4.1.2. Planned large hydropower plants

Based on available technical documentation and hydrological bases [16], potential large HPP are listed in Table 3. Some of them are in a phase of construction; some of them are in a procedure of tender and for some of them the tender procedure has been finished, while there are few that are still in a study phase.

Total installed capacity of all planned large HPPs is approximately 960 MW, with average annual electricity production of 2270 GWh. Total electricity production from planned large HPPs will vary, depending on hydrology and technical realization of HPP Čebren and HPP Galište as reversible HPP or regular HPP. Investments for all planned large HPP are estimated at 1.53 billion €.

Table 2
Basic characteristics of existing large HPP in Macedonia.

Name of HPP	River basin	No. of turbines	Q_{inst}/turbine (m^3/s)	H_{gross} (m)	Vol (10^6 m^3)	P_{inst} (MW)	W_{ann} (GWh)	First time operational (year)
Vrben	Mavrovo	2	4.6	193	0	12.8	45	1957/1973
Vrutok	Mavrovo	4	9	574	277	172.0	390	1959/1973
Raven	Mavrovo	3	10.6	66	0	21.6	53	1959
Tikveš	Crna reka	4	36	100	272	116.0	184	1966/1981
Kalimanci	Bregalnica	2	9			13.8	17	2006
Globočica	Crn Drim	2	27	110.9	228	42.0	213	1965
Špilje	Crn Drim	3	36	95	212	84.0	300	1969
Kozjak	Treska	2	50	102	260	88.0	150	2004
Matka*	Treska	2	20	28	1.1	9.6	40	2009
Total						559.8	1392	

* HPP Matka is considered large since it has almost 10 MW installed capacity and a storage lake

Table 3
Potential planned large HPP in the Republic of Macedonia.

Name of potential HPP	River basin	$P_{inst.}$ (MW)	W_{ann} (GWh)	Investment mil (€)	Planned period of construction (years)
Sv. Petka[a]	Treska	36	60		
Boškov most	Radika	68.2	134	70	4
Lukovo pole and HPP Crn Kamen[b]	Mavrovo	8.0	140	45	4
Galište	Crna Reka	193.5	264	200	7
Čebren[c]	Crna Reka	333.0	340	319	7
Gradec	Vardar	54.6	252	157	7
Veles	Vardar	93.0	300	251	7
Vardar Valley (10 HPPs)	Vardar	176.8	784	486	7
Total		963	2274	1528	–

[a] Sv. Petka is in construction phase and it will be operational in 2011
[b] HPP Crn Kamen is new HPP with installed capacity of 5 MW, while 140 GWh is planned additional electricity production from all Mavrovo HPP's
[c] Čebren is Reversible Hydropower plant (RHPP) with annual operating costs for pumping of 786 GWh

4.1.3. Existing small HPP

According to available data from EVN (largest owner of small HPP in the country), and some of the water supply utilities that own SHPP [17], the characteristics of existing SHPP are given in Table 4.

Total installed capacity of existing SHPP is around 28 MW with average annual electricity production of around 80 GWh. Engagement of SHPP in electro-energetic system of the country is calculated through capacity factor, CF:

$$CF = \frac{W_{ann}}{8760\,P_{instal}}$$

where W_{ann} (MWh), annual production of electricity and P_{instal} (MW), installed capacity for electricity generation.

For determination of electricity production from SHPP in this article, CF = 0.3 will be used.

4.1.4. Planned small HPP

There are over 400 potential locations for small HPP in the country, with total installed capacity of around 258 MW and estimated average annual electricity production of around 1100 GWh [14]. Some of these locations were additionally studied through feasibility studies and projects, and the Ministry of Economy has already issued 3 tenders for concessions of best and most perspective locations. Out of 85 SHPP offered on tenders, so far 71 SHPP with installed capacity of over 65 MW have past the tender procedure and are in a primary phase of construction. Estimated average annual electricity production of these SHPP with capacity factor CF = 0.3 is around 175 GWh.

4.1.5. Comparison between existing and planned hydropower potential

Comparison between existing and planned large and small HPP in the Republic of Macedonia is given in Table 5. Graphical reviews of existing and planned installed capacity of HPPs as well as existing and estimated electricity production from planned HPPs are given in Figs. 3 and 4, respectively.

4.2. Biomass

Biomass has significant place in country's energy balance. It participates with 166 ktoe (1930 GWh; 6950 TJ), which is 11.5% of total energy production in the Republic of Macedonia (data from 2006) [18], or 6% out of the total consumption of primary energy and 9.5% of the total consumption of final energy. Biomass for heating participates with 53% in the usage of RES in the country.

Biomass is mainly used for heating of household, satisfying approximately 30–33% of total energy needs. Around 430,000 households (76% of total number of households) use biomass for heating.

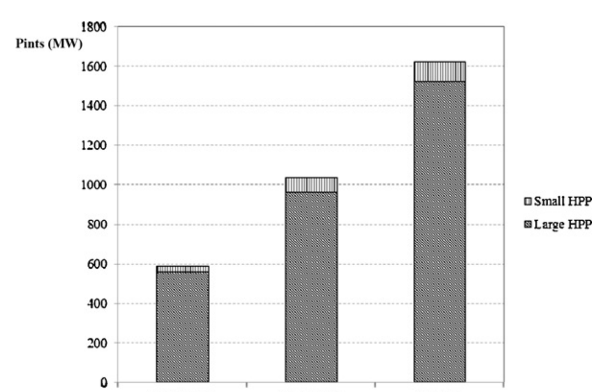

Fig. 3. Installed capacity of existing, planned and total HPP (large and small) in the Republic of Macedonia.

Table 4
Existing SHPP in the Republic of Macedonia.

Name of existing SHPP	Q_{inst} (m^3/s)	P_{inst} (MW)	W_{ann} (GWh)	CF
Pena	2 × 2	3.3	9.43	0.33
Zrnovci	3 × 0.4	1.4	4.19	0.34
Pesočani	2 × 0.6	2.7	10.29	0.43
Sapunčica	2 × 0.4	2.9	9.96	0.39
Došnica	3 × 0.7	4.1	15.02	0.42
Turija	2 × 2.3	2.2	5.20	0.27
Modrič	1 × 0.4	0.2	0.43	0.20
Babuna	3 × 1.24	0.7	2.70	0.43
Belica	1 × 1	0.3	1.00	0.46
Glaznja	–	2.1	–	
Popova Šapka	4 × 0.6	4.8	18.00	0.43
Streževo 1	–	2.4	–	
Streževo 2	–	0.1	–	
Streževo 3	–	0.4	–	
Streževo 4	–	0.5	–	
Total		28.1	76.2	0.32

Table 5
Comparison of existing and planned hydropower potential in RM.

HPP	Existing		Planned		Total	
	P_{inst} (MW)	W_{ann} (GWh)	P_{inst} (MW)	W_{ann} (GWh)	P_{inst} (MW)	W_{ann} (GWh)
Large	559.8	1392	963	2274	1522.8	3666
Small	28.2	76.2	72.5	197	99.7	273.2
Total	588	1468.2	1035.5	2471	1623.5	3939.2

Types and regional diversity of biomass sources in Macedonia depend on the characteristics of each region. Biomass is largely represented in agricultural and forest regions of the country. Out of total biomass used for energy purposes, wood and charcoal comprise 80%. Branches from vineyard, rice husks and branches from fruit trees are also used as energy source, but substantial quantity of straw is used as fertilizer and fodder for obtaining cellulose thus making it unavailable for energy purposes.

Total area under forest, forest crops and intensive plantations [19], is approximately 38.8% of the total area of the country, which is relatively high percentage compared to Europe (29.3%) and neighboring countries (Serbia 26.2%; Bulgaria 28.7%; and Greece 16%). With density of around 82 m^3/ha, Macedonia is scarce with high quality forest. Around 71% of the area consists of low tree-trunks and degraded forest and with only 37% of the total wood mass (timber).

After 2005, Public enterprise Makedonski šumi (state owned company that plants, uses, and protects state owned forests), supplies the market with 600,000–750,000 m^3 of firewood and commercial timber per year [20], while in the private owned forests additional 120–180,000 m^3 of wood are marked for cutting. Around 90% of these quantities are broad-lived (deciduous) trees, while the rest are coniferous trees (Figs. 5 and 6; Table 6).

Waste biomass is composed of:

- waste cutting from forests;
- waste from wood processing;
- waste from agriculture;
- livestock waste;
- industrial waste; and
- solid communal waste.

Many studies for estimation of waste biomass potential in the Republic of Macedonia are done [21], and some of them are comprehensive [22], but still there is neither sufficient reliable data to estimate economic feasibility of this potential nor experience in the execution of plants for this purpose.

Waste cutting from forests reaches 70,000 m^3 annually, representing 8% of the total logging [22]. According to other research [23], waste from timber cutting is around 14% of the total logging (150,000 m^3). This is a result of outdated machinery used for log-

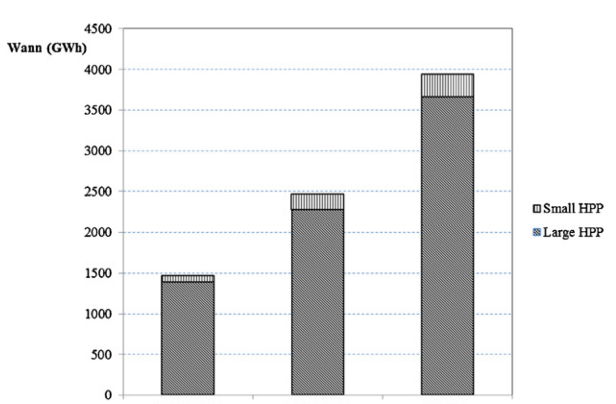

Fig. 4. Average annual electricity production of HPP (large and small) in the Republic of Macedonia.

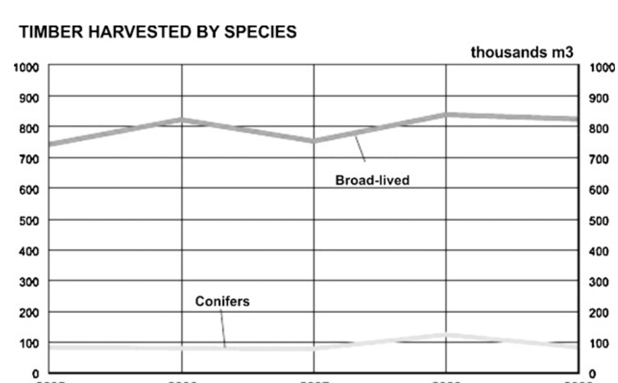

Fig. 5. Timber cutting by species in the Republic of Macedonia.

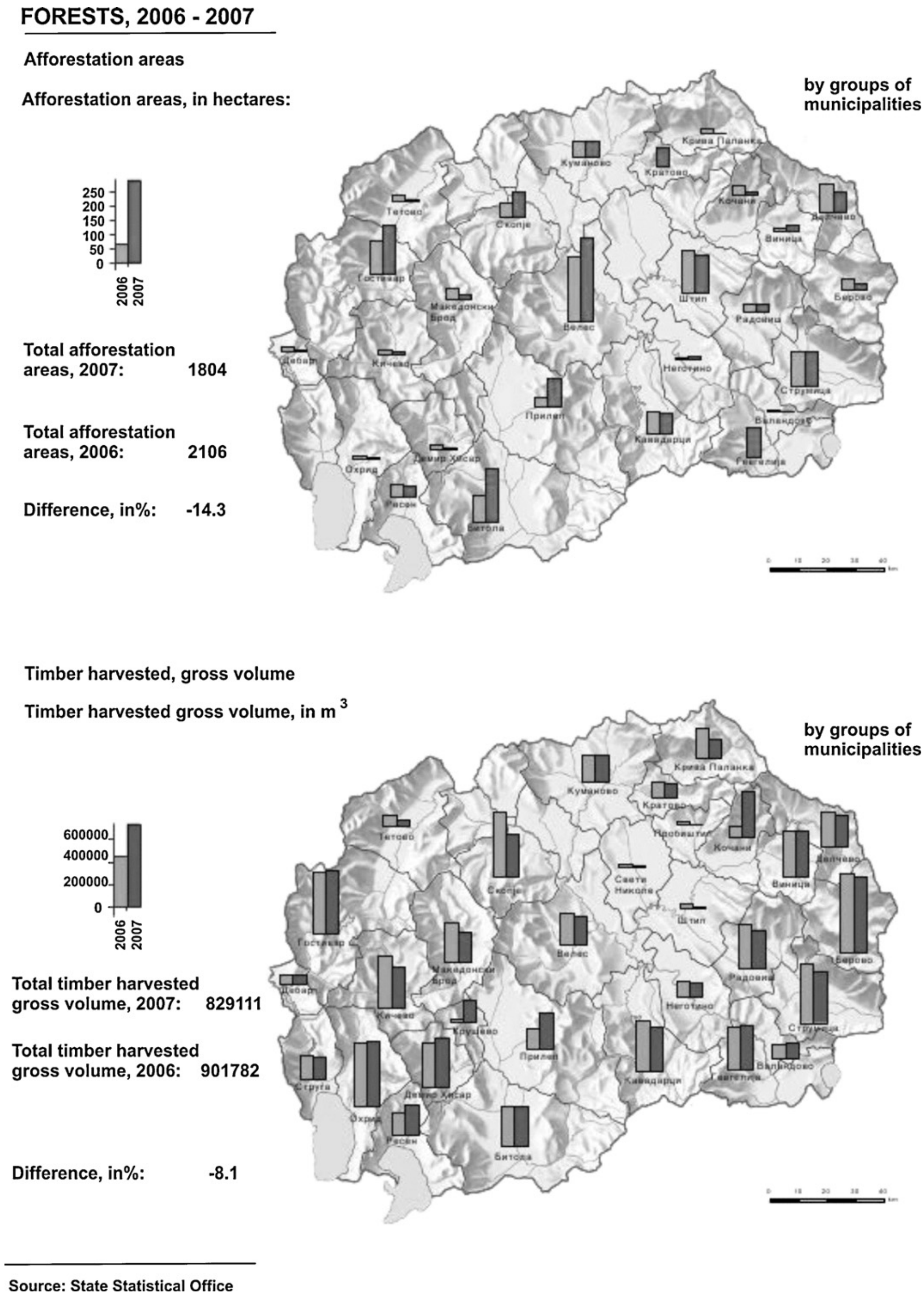

Fig. 6. Afforestation and timber cutting for period 2006–2007.

Table 6
Timber cutting in the Republic of Macedonia.

	Year				
	2005	2006	2007	2008	2009
In ‘000 m^3					
State-owned forests	682	717	688	762	683
Privately owned forests	139	184	141	199	223
Commercial timber	158	162	169	209	138
Firewood	600	662	583	646	666
Waste (scraps)	63	77	77	102	106
Total timber	821	901	829	961	906

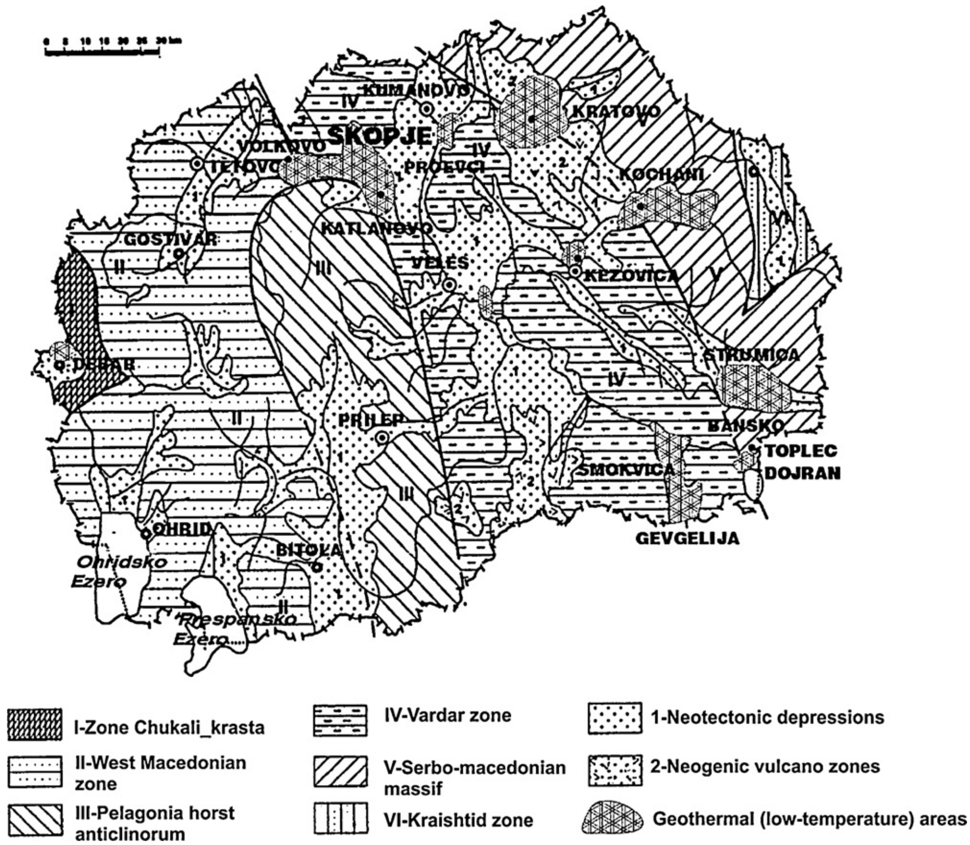

Fig. 7. Geology structure and geothermal fields in the Republic of Macedonia.

ging and intentional leftover of coarse waste for further unrecorded usage. According to same research, by using more sophisticated cutting technique, waste from cutting should not exceed 7% of the total logging, or approximately 75,000 m^3 annually. Very small amount of these quantity (around 40–100 m^3) is used by the companies themselves for space heating while the rest is left in the forest. Assuming that around 40% of the waste cutting from forest can be used in small cogeneration plants located at the nearest heat consumer, the usage of waste cutting from forest could reach around 30,000 m^3 per year.

160,000 m^3 of commercial timber per year are processed in Republic of Macedonia. There are around 100 companies working in this industry. Most of them are small sawmills. Part of the larger companies is producing carpentry and furniture while the others are dealing with primary and secondary wood processing. It is estimated [23] that larger companies process around 50,000 m^3 of wood annually generating around 18,000 m^3 of wood waste. Most of this waste is used by the companies themselves for steam generation and space heating. Smaller companies process around 110,000 m^3 of wood annually generating around 55,000 m^3 of wood waste. In general, this waste is not used for energy purpose, mainly because in most of these small companies there is no need for heat.

Total potential of waste from wood processing economically feasible for usage is estimated at 23,000 m^3 per year.

Branches from vineyard, branches from fruit trees, cereals and waste from food processing have significant energy potential in planned cogeneration production of heat and electricity in the Republic of Macedonia. They are partly used for heat generation now.

Total waste biomass from agriculture economically feasible to be used in combined heat and electricity production is estimated at approximately 35,000 tons per year.

Solid communal waste is the waste collected from households together with maintenance of public hygiene and collecting of waste from the parks, commercial buildings, construction waste and waste from industry which is similar to waste from households.

Solid communal waste in the country is deposited in large number of landfills. Among them, only landfill Drisla, serving the region of Skopje, is well managed. Seven regional landfills are planned in the Republic of Macedonia [23]. Total quantity of solid communal waste in the country is approximately 700,000 tons per year. Out of this figure, around 200,000 tons are deposited in regional landfill Drisla, while approximately 50,000–100,000 tons are deposited in each of the other regional landfills. Lower calorific value of solid communal waste is estimated at 7860 kJ/kg [24]. In this estimated value, waste from paper and plastics participates in the total mass of waste with 24% and 6%, respectively. If an average degree of paper and plastics recycling reaches 50%, quantity of solid waste will be reduced to 600,000 tons per year with lower calorific value of 6200 kJ/kg. If the percentage of recycling is higher than 50%, the amount of waste and its calorific value will decrease even more. Depending on realization of either variant, energy potential from solid communal waste in the Republic of Macedonia is around 500–1500 GWh per year. If complete potential is used only for electricity generation, that would mean production at the level of 200–500 GWh per year. In an optimistic scenario, it is hardly possible to reach production of 20 GWh per year of electricity from solid communal waste until year 2020. Landfills, especially Drisla are far away from heat consumers and if plants are planned in the

Fig. 8. Global irradiation and solar electricity potential of horizontally mounted photovoltaic modules in the Republic of Macedonia.

vicinity of cities, it would be conditioned by extremely high costs for environmental protection.

Waste from agriculture, mainly manure, is used as energy only in the form of biogas gained through anaerobic fermentation. Biogas is composed of methane and carbon dioxide in the ratio 2:1 and from small amounts of NH_3 and H_2S. In Macedonia, total annual quantity of waste from agriculture is estimated at 3.5 million tons, which is equal to 90,000 m^3 biogas annually with total energy gain of 600 GWh. Despite this potential, experience with the biogas in the neighboring countries is not favorable, and percentage of usable potential reaches only up to 25% of the available quantity. It is estimated that only 50 GWh of energy can be obtained from this energy source per year.

4.3. Geothermal energy

Territory of the Republic of Macedonia belongs to Alps-Himalayan zone, with subzones without any ongoing volcano activity. This area is between Hungary on north, through Serbia, Macedonia and Northern Greece up to Turkey. Several geothermal regions have been determined, all connected to Vardar tectonic unit. This region contains positive geothermal anomalies and a lot of geothermal systems. Hydrology systems are, at the moment only economically feasible for further examination and research, Fig. 7.

There are 18 geothermal fields in the country with more than 50 geothermal springs, boreholes and hot water springs. Total water flow reaches 1000 l/s with temperatures in the range of 20–70 °C. All thermal springs in the country are of meteoric origin.

Macedonia has extensive experience in the utilization of geothermal energy. However, in the last 20 years there has not been significant investment in utilization of geothermal energy. There were no investments neither in research nor in the development of new projects. As a result of this, the utilization of geothermal energy in recent years has significantly decreased. From 21 ktoe per year in 2001 it dropped to around 9 ktoe (around 400 TJ; 110 GWh) per year. The share of the geothermal energy in the total primary energy supply (TPES) of the country is less than 0.5%.

Utilization of this potential for energy needs is on local level. Due to its relatively low temperature (highest temperature is 78 °C in the Kočani region), it is mainly used for heating of greenhouses. In the industry (also Kočani region) it was used for heating of commercial building and preparation of hot water for the paper mill that is not in function for a longer period.

The geothermal potential of the country is 173 MW, with maximum production capacity of 210 GWh per year [25]. However, the explored potential for geothermal energy shows that there are no sources for generation of electricity in the Republic of Macedonia. For that purpose, temperature of geothermal energy of at least 120 °C is required for the investment to be economically feasible. Certain studies indicate that at depth of around 5000 m, possible steam deposits with temperatures above 100 °C can be found. The price for drilling of well at such depth usually exceeds

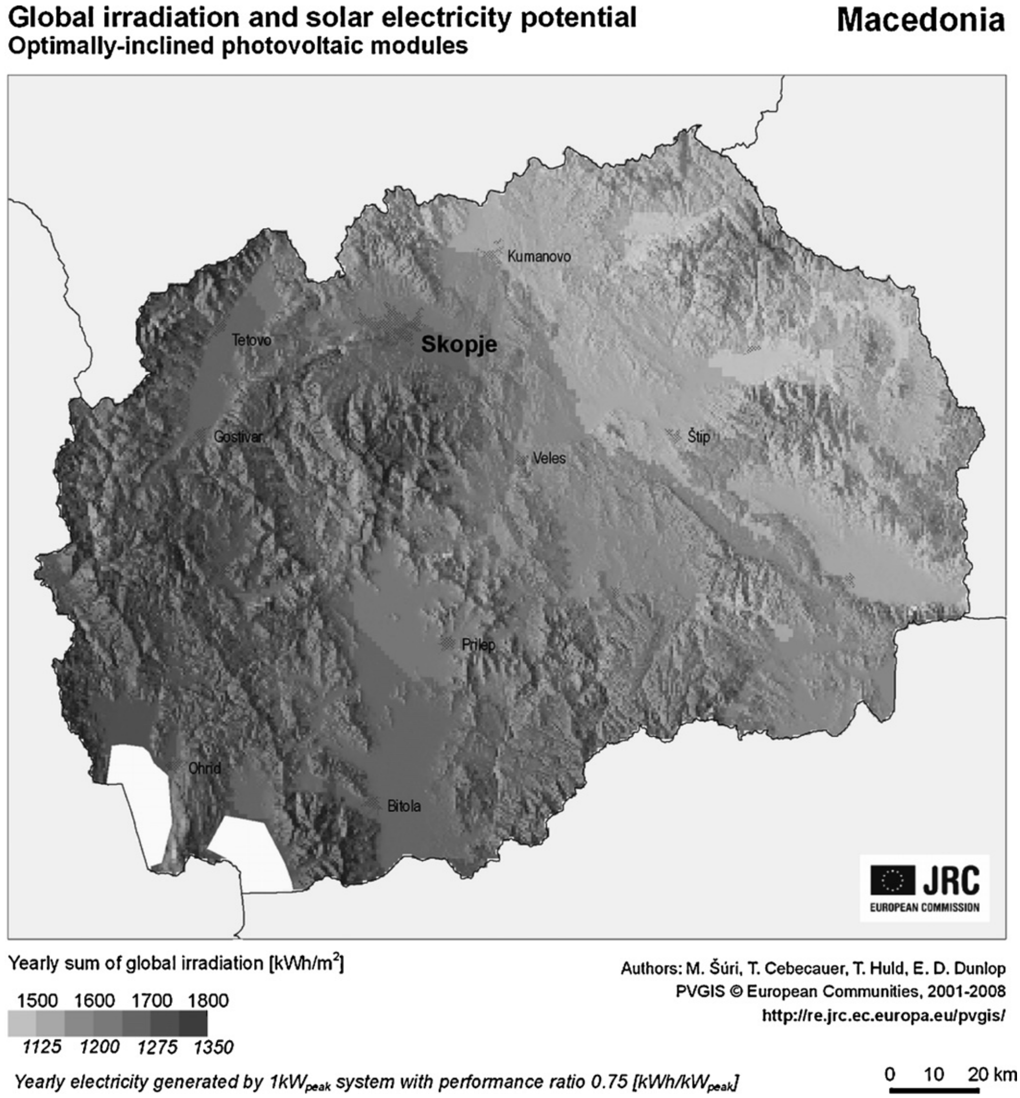

Fig. 9. Global irradiation and solar electricity potential of optimally inclined photovoltaic modules in the Republic of Macedonia.

1 million dollars per hole. This cannot be covered by the current prices for electricity generated by energy source of this type [26].

4.4. Solar energy

Solar energy is used at symbolic level for heating of water in households. Geographic position and climate in the country offer very good perspective for utilization of solar energy. Annual average value for daily irradiation varies from 3.4 kWh/m^2 in the northern part of the country (Skopje) to 4.2 kWh/m^2 in the southern part (Bitola). Total annual solar insolation varies from 1250 kWh/m^2 in the northern part up to a maximum of 1530 kWh/m^2 in the south-western part leading to annual solar insolation of 1385 kWh/m^2 (Figs. 8 and 9) [27]. Climate

Table 7
Absorbed solar energy for Bitola, Kočani and Skopje.

Month	Bitola		Kočani		Skopje	
	kWh/m^2/d	kWh/m^2/m	kWh/m^2/d	kWh/m^2/m	kWh/m^2/d	kWh/m^2/m
January	0.66	20.46	0.64	19.90	0.57	17.67
February	1.30	36.40	1.52	42.50	1.20	33.60
March	2.20	68.20	2.26	70.20	2.03	62.93
April	2.83	84.90	2.96	88.75	2.56	78.80
May	3.01	93.31	3.23	100.20	3.24	100.44
June	3.58	107.40	3.55	106.50	3.08	92.40
July	3.92	121.52	3.80	117.70	4.03	124.82
August	4.62	143.22	4.55	141.00	4.87	150.97
September	3.60	108.00	3.12	93.75	3.57	107.10
October	2.45	75.95	2.40	72.45	2.18	66.96
November	1.50	45.00	1.28	39.70	1.08	32.40
December	0.71	22.00	0.67	20.70	0.61	18.91
Annually		926.36		913.35		887.00

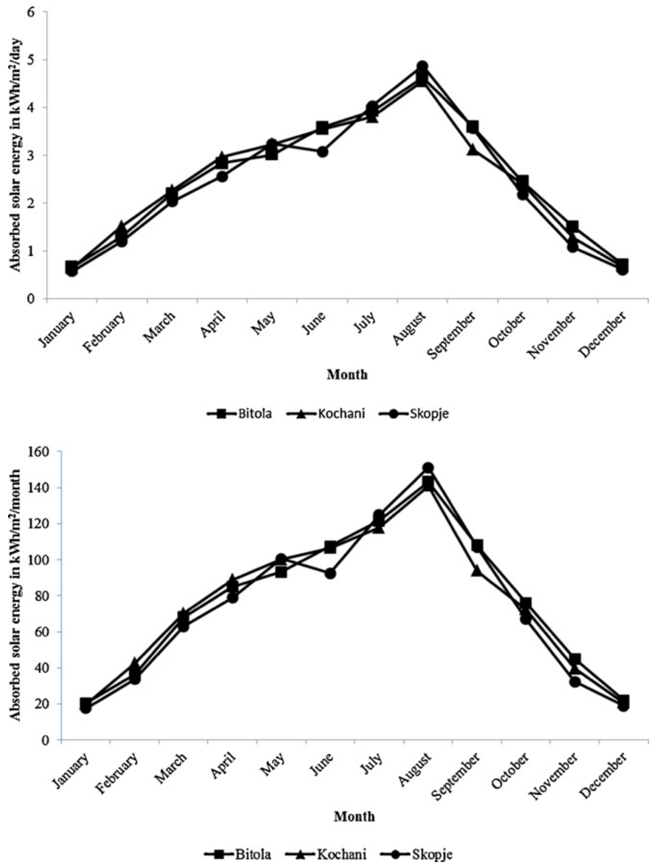

Fig. 10. Diagrammatic representation of the results from Table 7.

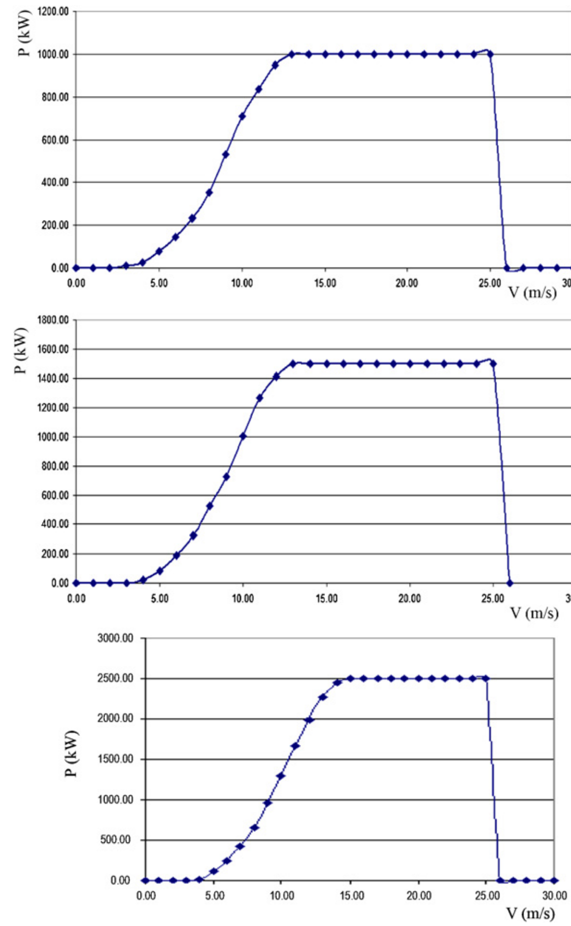

Fig. 11. Energy characteristics of 3 commercial wind turbines with different power output.

characteristics – high solar irradiation intensity as well as its duration, temperature and humidity enable favorable preconditions for development of solar energy.

In the year 1988, Macedonian Academy of Sciences and Art (MANU) made study for the annual quantity of absorbed energy from flat panel thermal collectors for three cities in the Republic of Macedonia: Bitola, Kočani and Skopje. Results from the study are shown in Table 7 and Fig. 10.

The immense solar energy potential with 2000–2400 sunny hours during the year and generation potential of around 10 GWh per year can satisfy at least 75–80% of the annual needs for space heating and sanitary hot water. Currently its usage is limited to water heating. In Macedonia there are only 7.5 m^2 solar panels on every 1000 people, or 15,000 m^2 of installed solar panels. At the end of 2006 the total collector area in operation in Macedonia was 17,118 m^2. For example, in Cyprus this area was 811,538 m^2, while in Germany it was 1,160,400 m^2 [28]. Out of 500,000 households in Macedonia only 2500–3000 are using solar systems for water heating. This represents only 0.5% of the total market for solar panels [29].

Apart from the advantages of solar energy for a country like Macedonia situated on the south of Europe, poor with domestic energy resources but with long-term tradition of theoretical and experimental research in the field of photovoltaic systems, practical application of these systems is still limited to few pilot-installations in telecommunication facilities and street lighting in several municipalities.

In order to encourage investment in photovoltaic systems, ERC has recently adopted preferential tariffs for sale of electricity produced and supplied by photovoltaic systems. With these tariffs, investment in photovoltaic systems will become much more cost-efficient, but their implementation requires elimination of technical, administrative and legal barriers.

4.5. *Wind energy*

Utilization of wind energy is particularly actual issue and most exploited one for generation of electricity from all types of renewable energy sources. According to geographical position, locations suitable for the use of wind power are divided into locations besides sea shore (offshore sites) and locations in the continental part (inland sites). Due to meteorological conditions and circulation of air masses, locations beside the sea coast are more favorable for building of wind farms. For countries like Macedonia, landlocked and surrounded by mountain ranges, further investigations are required in order to pinpoint suitable locations for building of wind farms.

According to international classification, potential sites for construction of wind farms are divided into classes [30], according to wind power density (WPD), or simply said, velocity of the wind. Classes are given in Table 8.

Wind power plants (wind farms) are built as a complex of several individual wind turbines, which provide energy integrally through connection of wind farm with electro-energetic system. The choice of commercial wind turbines depends on the choice of developer and designer of wind farm. Almost all commercial wind turbines operate in range of wind velocities from 4 m/s to 25 m/s, but the velocity at which the installed capacity of the wind turbine is reached is around 12 m/s. In order to estimate the energy potential of the wind (where measured values of wind velocity exist), three

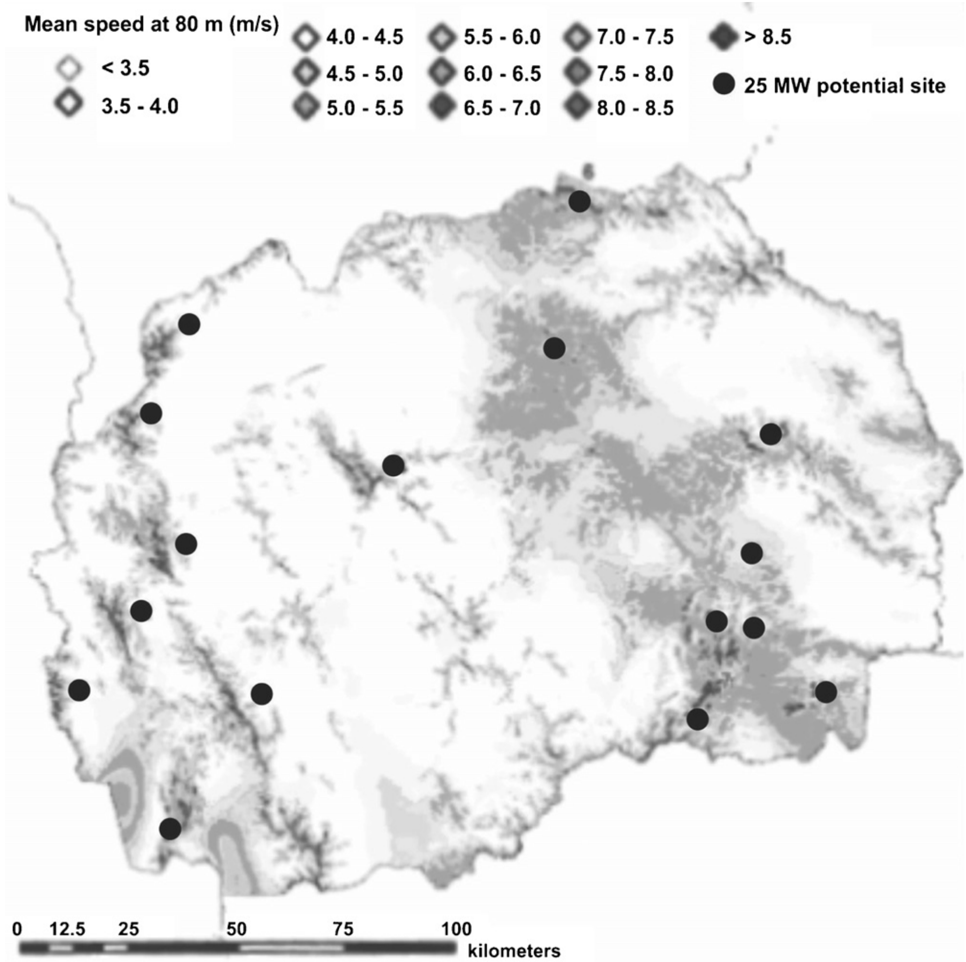

Fig. 12. Map of most favorable locations for building of wind farms.

Table 8
Classification of winds according to energy density and velocity of wind at height of 10 m and 50 m above ground.

10 m			50 m		
Class	WPD[a] (W/m^2)	v (m/s)	Class	WPD (W/m^2)	v (m/s)
1	<100	<4.4	1	<200	<5.6
2	100–150	4.4–5.1	2	200–300	5.6–6.4
3	150–200	5.1–5.6	3	300–400	6.4–7.0
4	200–250	5.6–6.0	4	400–500	7.0–7.5
5	250–300	6.0–6.4	5	500–600	7.5–8.0
6	300–400	6.4–7.0	6	600–700	8.0–8.8
7	>400	>7.0	7	>800	>8.8

[a] WPD = 0.5 ρv^3, where ρ and v are density and velocity of wind, respectively.

types of commercial wind turbines are shown in Fig. 11 represented with their energy characteristics.

So far, several studies for determination of most suitable locations for construction of wind farms have been made in Macedonia. According to a study prepared by AWS Truewind [31], atlas of wind energy potential of Macedonia is made. 15 most suitable locations for building of wind farms determined from this study are shown in Fig. 12. Wind map of the country is also shown.

Four locations [32], are selected from the wind atlas and from 2006 onwards, continuous measurements of wind velocity, wind direction and other meteorological parameters are taken. Preparations for measurements on additional five locations are ongoing.

According to the wind map and according to measured values at 4 locations, projected installed capacity by location varies from 20 MW to 30 MW. The choice of single turbine and number of turbines and their disposition in each location requires further investigations on the location configuration and investors possibilities. Measured data in Macedonia indicate that the effective factor of wind farm with installed capacity of 30 MW is between 0.13 and 0.25. This means that expected annual production of electricity from wind farm with installed capacity of 25 MW is in the range of 30–55 GWh.

Real possibilities for building of wind farm in Macedonia exist on 6 most suitable locations (first group), with total installed capacity ranging from 150 MW to 180 MW, which is, at the moment, around 10% of the total installed capacity of electricity production plants in the country. Expected annual electricity production from these 6 locations is 300–360 GWh.

5. Conclusion

The issue of the renewable energy sources in Macedonia remains on the level of political rhetoric, with neither strategy nor clear political will to move forward and to introduce the renewable energies in the energy sector in the country. Being aware that the energy sector in Macedonia has been developing with a very slow pace since the country's independence, it is not a surprise that the renewable energies have remained on the last place of the priorities in the energy sector. With no electricity production from RES and no set targets for renewables for energy production Macedonia risks staying at the bottom of the RES map in Europe, with

inefficient energy market that is highly dependent on fossil fuels and uncompetitive in the liberalized electricity market of the EU.

Increasing of the share of electricity produced from renewable energy sources is not possible without appropriate (supportive) legislative and regulations. Another major obstacle is lack of institutional support. Legislation should provide framework, which will allow easier construction of power generating facilities, incentive (financial) measures and implementation of incentive measures. The biggest problem, especially when it comes to building plants with smaller installed capacity, is a complex procedure for obtaining building permits, the right to use land and acquiring the status of electricity producer.

In order to comply with the EU directives of the renewable energy and to provide a sustainable energy development of the country, in the upcoming period the Macedonian government will have to undertake more efficient energy policies that will comprise the energy production from renewable energy sources, and explicitly encourage electricity production from RES. The energy crisis in the electricity sector in Macedonia urges for a thoughtful and timely actions. Therefore, after adaptation of the National Energy Strategy and National Strategy for utilization of renewable energy sources, the government should reconsider and give priority to renewable energies as a domestic, clean and cheap source of energy and finally resolve the issues such as security of energy supply and energy stability of the country for the future generations.

Despite the changes and completion of legislation, and in particular their consistent application, in order to meet the planned participation of RES in country's energy balance, additional specific activities for each object are required.

Following the analysis conducted in Chapter 4 of this article, utilization and potential of hydropower and biomass prevail in country's RES energy mix. Accordingly, particular attention should be paid to the rational use of existing and planned hydropower potential and biomass.

References

[1] International Energy Agency. Press release (29 September 2008), available at: http://www.ies.org/Textbase/press/pressdetail.asp?PRESS_REL_ID=271.
[2] Energy balances, State Statistical Office, Press release issued on 30 June 2010, available at: http://www.stat.gov.mk/statistiki.asp?ss=11.06&rbs=1; 2008 [in Macedonian and English].
[3] Balance of electrical energy by months, State Statistical Office, Press release issued on 30 April 2010, available at: http://www.stat.gov.mk/statistiki.asp?ss=11.06&rbs=5; 2008 [in Macedonian and English].
[4] Strategy for usage of renewable energy sources in Macedonia until year 2020. Skopje: Makedonska akademija na naukite i umetnostite (MANU); 2010 [in Macedonian].
[5] Law on energy. Official gazette of Republic of Macedonia, No. 63/2006, 36/2007 and 106/2008 [in Macedonian].
[6] Official gazette of the Republic of Macedonia, No. 16/2007 [in Macedonian].
[7] Official gazette of the Republic of Macedonia, No. 61/2007 [in Macedonian].
[8] Official gazette of the Republic of Macedonia, No. 142/2007 [in Macedonian].
[9] Official gazette of the Republic of Macedonia, No. 44/2010 [in Macedonian].
[10] Official gazette of the Republic of Macedonia, No. 112/2008 [in Macedonian].
[11] Official gazette of the Republic of Macedonia, No. 127/2008 [in Macedonian].
[12] Official gazette of the Republic of Macedonia, No. 29/2009 [in Macedonian].
[13] Renewable energy in Macedonia, focus on green electricity production, Analytica MK, available at: http://www.analyticamk.org/files/ReportNo20.pdf [accessed December 2008].
[14] Study for potential small and mini hydropower plants in the Republic of Macedonia. Ministry of Economy and Macedonian Sciences and arts academy; 1982 [in Macedonian].
[15] Energy sector development strategy for Macedonia - final report. Ministry of Economy, Research Center for Energy Informatics and Materials of the Macedonian Academy of Sciences and Arts and Electrotek Concepts Inc.; 2000.
[16] Documentation of AD "ELEM", available at: http://www.elem.com.mk.
[17] Public enterprise hydro system "Streževo" existing small hydropower plants characteristics, available at: http://www.strezevo.com.mk/index.php?option=com_content&task=view&id=44&Itemid=43&lang=eng.
[18] ©OECD/IEA. IEA online database: energy balances of non-OECD and OECD countries and energy statistics of non-OECD and OECD countries; 2008.
[19] Strategy for sustainable forestry development in the Republic of Macedonia. Ministry of agriculture, forestry and water management of RM; 2007 [in Macedonian].
[20] Statistical Yearbook of the Republic of Macedonia for 2010. State Statistical Office, available at: http://www.stat.gov.mk/pdf/SG2010/10.%20Zemjodelstvo.pdf [in Macedonian and English].
[21] Biomass availability study for Macedonia. A.B. van der Hem, SENTER project PSO99/MA/2/2; February 2001.
[22] Armenski S. Energy from biomass, Skopje; 2009 [in Macedonian].
[23] National strategy for investments in the environment (2009–2013). Ministry of environment and spatial planning of RM; 2009 [in Macedonian].
[24] Armenski S. Energy from solid municipal waste. In: Popovski K<ETAL>, editor. Renewable energy sources. Skopje: MAGA; 2006 [in Macedonian].
[25] Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA), Ibid, 52.
[26] Energy Sector Policy note. World Bank, Report No. 48983-MK; 2009.
[27] European Commission, Joint Research Centre. European solar test installation, geographical assessment of solar resource and performance of photovoltaic technology, available at: http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_hor/pvgis_solar_horiz_MK.png, http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_opt/pvgis_solar_optimum_MK.png.
[28] Weiss W, Bergman I, Faniger G.Solar heat worldwide. 2008.
[29] Data from Eterna Solar website, available at: http://www.eternasolar.com.mk.
[30] American Wind Energy Association, available at: http://www.awea.org/faq/basicwr.html.
[31] Wind energy resource atlas and site screening of the Republic of Macedonia. AWS Truewind; 2005.
[32] Pilot project – Wind farm. Skopje: AD "ELEM"; 2008 [in Macedonian].